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TREATMENT
OF
TANNERY WASTES

Processes found as the outcome of six years study by the Tannery Waste Disposal Committee of Pennsylvania created by the agreement of 1924 between the Sanitary Water Board and Leather Tanning Companies.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HEALTH

THEODORE B. APPEL, M. D., *Secretary of Health*
W. L. STEVENSON, *Chief Engineer*
F. B. MILLIGAN, *Resident Engineer*

HARRISBURG
December, 1930

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December, 1930

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December 24, 1930.

To his Excellency John S. Fisher,
Governor of Pennsylvania,
Harrisburg.

My dear Governor:

I herewith transmit reports relative to "reasonable and practicable" processes for the treatment and disposal of waste waters resulting from the vegetable tanning of leather.

The solution of this hitherto unsolved problem is the result of six years cooperative study made under an agreement between the Sanitary Water Board of Pennsylvania and the leather tanners of the State.

Representatives of the tanners met with the Sanitary Water Board on November 25, 1930, and after a general discussion of the Tannery Committee Report, it was endorsed by the representatives of the companies. Thereupon, the Sanitary Water Board made the following proposal, applicable to all companies operating tanneries using the vegetable process and whose waste waters are not disposed of by admission to public sewer systems, to wit:

Such tannery companies

(1) To collaborate with engineers of the Sanitary Water Board to determine (a) the rate of flow and composition of their waste waters, (b) the existing means of treatment, (c) the use and condition of the receiving streams and (d) the first and ultimate steps of treatment set forth in the Committee Report indicated as needed after consideration of above.

(2) To select a site suitable for erection of such treatment works and submit to the Sanitary Water Board for approval a comprehensive plan showing in detail the works needed to effect the first step of treatment and in general outline the ultimately needed further steps.

(3) To construct and efficiently operate such first step of the treatment works subsequent to approval of plans by Sanitary Water Board.

(4) To sample and analyze the influent and effluent of such first step of the tannery waste treatment works and also of the receiving stream both prior and subsequent to installation of the first step so as to determine efficiency of operation of such first step and the reduction in load upon the stream resulting from the first step in treatment of the tannery wastes.

(5) Where there is need for the second step, after the efficiency of the first step has been demonstrated or changes made to produce a settled effluent suitable for application to the primary trickling filter included in the second step, then plans of such second step to be submitted to the Sanitary Water Board and, after approval thereof, constructed and operated.

After a discussion of this program, it also was endorsed by the representatives of the tanning companies.

The joint study set forth in item one is about to be made.

This noteworthy step for the protection of the waters of the State was attained through a spirit of good faith on the part of both the Sanitary Water Board and leather tanners of Pennsylvania, the pooling of technical knowledge by all parties to the tannery agreement, and the zeal and skill of the engineers and chemists who were in charge of the investigatory work.

The conservation of water resources, with special reference to the treatment of sewage and industrial wastes, is a subject of rapidly growing importance not only in Pennsylvania but throughout the United States and because Pennsylvania began cooperative investigations of tannery waste six years ago the officials of other states have, to a considerable extent, depended upon the outcome of our investigations instead of duplicating such work in their own state. We have, also, followed this same policy in regard to other industrial wastes and in the meantime have received from other states the results of their cooperative investigations.

This economy of public funds through exchange of data is a policy of nationwide extent through the State and Territorial Health Officers of North America, an organization consisting of the heads of all the State Health Departments of the United States. It is also a definite policy of the Commissioners of Health, signators to the Ohio River Inter-State Stream Conservation Agreement and of the Great Lakes Drainage Basin Sanitation Agreement, which include the Health Departments of the fourteen States lying in the drainage basin of the Ohio River and the Great Lakes.

On account of the importance of these documents primarily in Pennsylvania, and secondarily, to the other States in the Union, I recommend that they be promptly printed as a State publication.

Respectfully submitted,

THEODORE B. APPEL, M. D.,
Secretary of Health,
Chairman, Sanitary Water Board.

REPORT ON THE TREATMENT AND DISPOSAL OF VEGETABLE TANNERY WASTES

October 18, 1930.

Theodore B. Appel, M. D.,
Secretary of Health,
Chairman, Sanitary Water Board

Dear Sir:

On October 8, 1930, the Tannery Waste Disposal Committee of Pennsylvania endorsed and approved a report entitled, "A Condensed Report by the Tannery Waste Disposal Committee of Pennsylvania to the Sanitary Water Board on the treatment of Tannery Wastes" and authorized and directed the undersigned as Chairman of the Committee to transmit copies thereof to the Sanitary Water Board and to all Tannery Companies parties to the second supplement of the original agreement of July 30, 1924.

In complying therewith the aforesaid report is hereby transmitted and commented upon as follows:

Processes for the treatment of waste waters resulting from the vegetable tanning of leather have been found and demonstrated in full scale experimental plants by the "Tannery Waste Disposal Committee of Pennsylvania" which was created by the agreement of 1924 between the Sanitary Water Board and tannery companies of the State.

This is such an outstanding instance of the success attainable through cooperation between the State authorities and industry that a brief history of the matter is in order.

The Sanitary Water Board, created by the Administrative Code of 1923, was charged by that legislative act with the duty, inter alia, "to study, investigate, and, from time to time, report ways and means of eliminating from the streams and waters of the Commonwealth, so far as practicable, all substances and materials which pollute or tend to pollute the same," etc.

The Board knew that Pennsylvania was a leading State in the manufacture of leather and leather products; that the tanneries of the State had, in the aggregate, spent large sums of money for the installation of "rule of thumb" treatment works, the result being a benefit to streams inasmuch as material amounts of solids were removed but not commensurate with their cost, nor in many cases is the degree of treatment sufficient; that several short time investigations made of tannery waste treatment elsewhere had not produced results that had been actually applied and finally that tannery wastes were specifically exempted from the provisions of the "Purity of Waters Act."

These were the reasons prompting the Board to attempt to find through cooperation with industry, reasonable and practicable ways and means for tannery waste treatment in progressive steps and for disposal of the resulting sludge.

To that end Mr. M. J. Beach, President of the Elk Tanning Company, was invited to confer with the Sanitary Water Board on April 30, 1924, and when he understood that the purpose of the Board was to approach the problem of tannery waste disposal in a constructive

and scientific state of mind and through cooperation with the leather tanners of the State he proposed a meeting of the engineers and chemists of the State and of the tanning industry to discuss the scientific phases of the problem and to ascertain just what data on the subject were known to both groups.

Such a meeting was held in Harrisburg, June 11, 1924, and the conferees reached the conclusion that only through research in the laboratory followed by the construction and operation of a full scale experimental treatment works could a reasonable and practicable answer be found to the question at hand.

Thereupon, the Sanitary Water Board called a meeting of representatives of all leather tanning companies of Pennsylvania which was held in Harrisburg on July 30, 1924.

The idea of cooperation was proposed by the Board and accepted by the tanners. The Attorney General, George W. Woodruff, and Arch Jones, Esq., an attorney of the industry, drafted a form of agreement which was approved by the meeting and subsequently duly executed on behalf of the State authorities and of fourteen tannery companies.

The legislature of Pennsylvania has clearly declared its intent that such investigations shall be made under cooperative agreements, because funds are appropriated "for the cost of studies and investigations toward determining reasonable and practicable ways and means for the disposal of industrial wastes to be conducted either by the Sanitary Water Board, its employes and assistants or by the cooperation of the Sanitary Water Board pursuant to the provisions of duly executed agreements with persons, firms, corporations, municipalities or any groups thereof."

The original agreement of July 30, 1924, between the Board and the leather tanners provided for a fund of $35,000 to be proportionally contributed by the tanners, parties thereto, and created a committee of engineers and chemists of the industry with the Chief Engineer of the Sanitary Water Board as Chairman thereof; this Committee to be in charge of the investigations and to construct and operate a full scale experimental plant and make report thereon.

The Committee organized on September 22, 1924, and at once proceeded with the collection of basic data such as the quantity and composition of each of the different waste waters which go to make up tannery waste. Next came twenty months of thorough study in the research laboratory, of the effects of mixing certain of the acid and alkaline wastes together, the coagulating effects of different chemicals and like questions. Over a thousand such experiments were made.

Based upon these data, an experimental plant was constructed at Instanter, Pa., and operated during the summer and fall of 1926. It had to be abandoned due to the ceasing of operation of the railroad which served that tannery.

While it was operating careful studies were made at five stations along the twelve miles of the East Branch of the Clarion River below the plant, to scientifically determine the assimilating power for tannery waste treated to various degrees at various rates of flow of the stream.

The funds under the original agreement being nearly exhausted a supplement dated September 28, 1927, was executed extending the original agreement and providing further funds.

A new and improved full scale experimental treatment works was constructed at Emporium, Pa., and operated from the latter part of 1927 to October 7, 1930. There were also constructed and operated on the same site various experimental units of different kinds.

Again in the latter part of 1929 the funds of the Committee were nearly expended and a second supplement dated December 19, 1929, provided more money to complete the studies.

During the progress of these investigations many voluminous detailed reports were made by the engineers in charge of the work. They were Mr. W. Howalt, Assistant Chief Engineer, Elk Tanning Company, during the original laboratory research and the Instanter experiments and Mr. F. B. Milligan, Engineer for the Sanitary Water Board, during the investigatory work at Emporium.

By the summer of 1930, the investigations had cost about $83,000 and the Committee felt they had solved all the major problems. Only minor details need to be completed with the remaining funds available under the second supplemental agreement. The Committee, therefore, directed that a brief condensed report be prepared on the six years investigations and conclusions to be drawn therefrom.

Such report prepared by Engineer F. B. Milligan was considered by the Committee at its meeting on October 8, 1930. In final form it was endorsed and approved by the Committee and the Chairman directed to transmit it to the Sanitary Water Board and to tannery companies, parties to the agreement and supplements thereto.

For the sake of brevity here follows the most essential features of the approved report and comments thereon.

The principal departments of a tannery are:

(a) The Beam House, where hides are washed, fleshed, and unhaired.

(b) The tanning process, where hides are changed into leather by the use of solutions of various tannins.

(c) Drying and finishing.

The waste waters produced vary widely in volume, character and composition; some are acid while others are alkaline, some are released intermittently from vats and others are continuously produced during the operating day, some are small in volume and very concentrated and others are relatively large in volume but quite dilute and relatively clean.

The objectionable characteristics of the total raw waste waters of a tannery are—high oxygen demand, suspended, colloidal and dissolved matter and a reddish color. A typical analysis of raw wastes illustrates this point.

Suspended solids	2500 p. p. m.
Oxygen demand	1000 p. p. m.
Color	3500 p. p. m.

For comparison, ordinary domestic sewage would contain about:

Suspended solids	250 p. p. m.
Oxygen demand	100 to 200 p. p. m.
Color not comparable	

As there is a wide range in the size and capacity of the tanneries of Pennsylvania and they are situated on streams varying from large rivers to small creeks it was obvious to the Committee that to be successful in its work, progressive processes of treatment must be found to yield varying degrees of reduction in the objectionable constituents of the waste waters. This was done.

At the beginning of the report it is stated "Systems of treatment have been devised in successive steps, each providing an added degree of purification. It is believed that at most tanneries a plant can be installed capable of purifying the wastes to a degree necessary for their harmless assimilation by the stream into which they are discharged."

The complete general plan recommended as applicable to most vegetable process tanneries is as follows:

> "Mixture of all wastes as produced, their storage and settlement with uniform outflow during 24 hours; primary filtration, chemical coagulation if or when needed, resettlement; secondary filtration, chemical coagulation if or when needed, and resettlement."

Sludge from sedimentation and subsequent resettlement can be dried on underdrained graded cinder beds and disposed of by filling low areas.

The mixture of all wastes and their original settlement is to afford opportunity for reaction between the acid and the alkaline ingredients and the deposition of settleable material as sludge. The outflow over 24 hours instead of 8 hours (normal operation of a tannery) is to automatically reduce the otherwise peak 8 hour load by one-third which by itself is, defacto, equivalent to from 30% to 50% treatment, so far as peak load upon the stream at the point of discharge is concerned.

The filtration through coke in a trickling filter is to reduce the oxygen demand of the settled wastes. The resettlement is to deposit settleable solids passing through or at times unloaded from the trickling filter. The chemical coagulation, if or when needed, is primarily for color reduction and increasing the efficiency of resettlement.

Secondary filtration and resettlement is merely for higher purification, if or when needed.

These processes were successful at the Emporium tannery but at other tanneries where the waste waters might have slightly different characteristics, it cannot be yet positively stated that the same results will be attained.

The report, therefore, wisely states "It is not expected that the apparatus for a given step will be constructed at any tannery until the actual effect of the preceding step shall have been observed and tested. In the majority of cases chemical coagulation will be required only during droughts and emergencies and in many cases not at all."

In case the use and condition of the stream receiving the effluent of a tannery waste treatment works demands high removal of color the investigations demonstrated this can be attained by what the report calls the "Special Plan." This is based upon the Instanter and early Emporium experiments and consists of the admixture of certain intermittently produced wastes, some acid and others alkaline, their

quiescent sedimentation over night, next day adding the supernatant liquor to the continuous wastes, the acidulation and coagulation of the mixture with alum, and sedimentation, storage and discharge uniformly over the 24 hour day.

Now color removal generally is not essential—it is aesthetic. The present seeming dark brown color of streams below tanneries is not due to the water, it is reflected color from the stained stones on the bed of the stream. Ofttimes the water itself is as pale as very weak tea but the stained stones on the bottom give the stream the apparent color of very strong coffee.

It has not been demonstrated in actual practice but is probable that the use of the first and second steps of the general plan by actual removal of organic substances from the raw waste may materially minimize the ability of the effluent to stain the stones and thus show more evidence of color removal in the stream than expected.

In conclusion it is only just to make of record that the credit for solving this difficult problem is due to several parties—first, to the Sanitary Water Board for conceiving and putting into practice the idea of cooperation with industry; second, to the Leather Tanning Companies of Pennsylvania, who became parties to the agreement and provided funds; third, to the members of the technical committee who furnished a fund of knowledge concerning tannery practices gained by long experience and lastly to Mr. W. Howalt and Mr. F. B. Milligan who were in direct charge respectively of the Instanter and Emporium works.

Respectfully submitted,

W. L. Stevenson,
Chief Engineer,
Chairman, Tannery Waste Disposal
Committee of Pennsylvania.

A CONDENSED REPORT
(ABRIDGED)

by the

TANNERY WASTE DISPOSAL COMMITTEE
OF PENNSYLVANIA

to the

SANITARY WATER BOARD

on

THE TREATMENT OF TANNERY WASTES

October 8, 1930

EXPERIMENTAL TANNERY WASTE TREATMENT PLANT
EMPORIUM, PA.

AA	Settling Tanks (Fill and Draw)	F	Trickling Filter
B	Settling Tank (Flowing Through)	SS	Shallow Settling Basins
CC	Equalization Tanks	T	Sludge Trough
O	Operating House	DD	Sludge-Drying Beds
P	Small Pump House	EE	Experimental Filters, etc.

12 October, 1930

SURVEY OF CONCLUSIONS

There follows a brief outline of the more essential results of studies from 1924 to 1930 by the Tannery Waste Disposal Committee of Pennsylvania. These studies covered wastes from tanneries producing leather by the use of vegetable tanning materials, but did not include wastes from mineral tanning processes.

The Sanitary Water Board determines the degree of treatment of sewage and industrial wastes by the use and condition of the receiving stream. Therefore in general, the wastes from a small tannery on a large river may require little treatment, while for those from a large tannery on a small stream, nearly complete purification may be necessary.

Systems of treatment have been devised in successive steps, each providing an added degree of purification. It is believed that at most tanneries a plant can be installed capable of purifying the wastes to a degree necessary for their harmless assimilation by the stream into which they are discharged.

GENERAL PLAN FOR TANNERY WASTE TREATMENT: This is applicable to most tanneries. The following comprise the whole range of anticipated steps in treatment under this plan:—Mixture of all wastes as produced, storage and settlement, uniform outflow during 24 hours, primary filtration, chemical coagulation if needed, settlement, secondary filtration, coagulation if needed, and settlement. Periodic removal of sludge from all settlings tanks, or basins, is a general requirement.

It is not expected that the apparatus for a given step will be constructed at any tannery until the actual effect of the preceding step shall have been observed and tested. In the majority of cases chemical coagulation will be required only during drought and emergencies, and in many cases not at all.

SPECIAL PLAN: For certain tanneries at which high color reduction and removal of suspended matter is plainly required, and yet where reduction of polluting power need not be of the highest order, the various steps are:—Combination of certain wastes, settlement, chemical coagulation except during high water periods, settlement, uniform discharge during 24 hours. Where considerable all-around improvement (as well as color reduction) is required, chemical coagulation is more economical as well as more effective when applied after filtration, as under the general plan given above.

Lightening the color is relatively less effective, less uniform and more costly, to date, than is the improvement of the other objectionable qualities of tannery waste.

Based on costs at the Emporium experimental plant, the operating charge for the first of the foregoing degrees of treatment is estimated at 8 cents per 100 lbs. of leather; for the most complete treatment, 29 cents.

Table A, page 27, gives more extended data. On pages 22 to 27 will be found a fuller discussion of methods of treatment, and on pages 30 to 34 more complete cost figures.

INTRODUCTION TO BODY OF REPORT

NATURE OF THE PROBLEM: The problem of the disposal of tannery wastes is large and correspondingly important. Probably 50,000 men are employed in tanneries in this country. The Census of Manufacturers of 1921 ranks leather and its finished products as fifth in importance, and Pennsylvania first among the fourteen states now producing leather, based on the value of the product.

STREAM POLLUTION: Water is essential to life, and pure drinking water to health. Therefore, the use of streams for municipal and domestic water supplies is the first and highest use of water resources. Life in modern communities is impossible without adequate and clean water supplies; many industries must have such water for use in manufacture. Farmers need clean streams for watering stock; individuals for recreation. Streams, however, are the natural drainage channels of the land, and necessarily receive again the water which, after use as a domestic supply, becomes sewage, and after use in manufacturing becomes industrial waste.*

Tanning Process Sketched: The principal departments of an average tannery are:

(1) The beam house, where the hides are washed, fleshed, and unhaired, processes in which large amounts of water and unhairing chemicals are used.

(2) The tanning department, in which the hides are changed into leather by the use of various tannins, either vegetable or mineral. This requires the wastage of considerable quantities of liquid high in coloring matter.

(3) The drying and finishing departments, in which the various finishing compounds necessary to the manufacture of leather are used and from which a small volume of liquid waste is discharged.

PREVIOUS INVESTIGATIONS: The fact that the wastes produced in leather tanning are among the more objectionable industrial wastes has been recognized by the tanners themselves for many years. Since about 1910, individual tanneries have tried many methods of treatment—settling basins, screens, filters of all types, chemical disinfection, etc. The most efficient did not produce results sufficiently good to receive the approval of the State Health Departments concerned. Much experimental work has been done by various states and by the Federal Government, as well as by individual companies, but no generally accepted solution has been formulated.

THE TANNERY WASTE DISPOSAL COMMITTEE: On July 30, 1924, marking the inauguration of a policy of co-operation between the Commonwealth, as represented by the Sanitary Water

* Transactions, Am. Soc. of Civil Engineers, Vol. 92, p. 1326.

Board, and the tanning industry, the Tannery Waste Disposal Committee of Pennsylvania was formed. It is composed of engineers and chemists representing the tanners, its chairman is the Chief Engineer of the Department of Health, and it has functioned uninterruptedly during the past six years. There have been two supplemental agreements, the first dated Sept. 14, 1927, the second dated Dec. 19, 1929. Both are similiar to the original agreement.

The tanners have contributed $57,000, and under the agreement the Board has expended $28,000 for experimental work in the effort to find a reasonable and practicable solution of the problem.

Aims of the Tannery Waste Disposal Committee: These have been to determine:

(1) The nature and polluting strength of the ingredients of tannery waste.

(2) The assimilating capacity of streams for this waste, untreated and treated to various degrees.

(3) Reasonable and practicable processes of treatment in successive steps, each giving an added amount of purification, so as to meet the requirements of different streams.

(4) Cost data of construction and operation.

SCOPE OF INSTANTER INVESTIGATIONS

by

THE TANNERY WASTE DISPOSAL COMMITTEE

July 1924 to May 1927

These investigations are recorded in detail with full supporting data, in earlier and voluminous reports and the more essential features are described in a paper entitled "Studies on Tannery Waste Disposal," by Messrs. Howalt and Cavett. This paper was published by the American Society of Civil Engineers in Vol. 92, p. 1351 et seq. of its transactions, 1928.

PROGRAM: Extensive laboratory studies were considered an essential part of any thorough investigation, to be followed by the construction and operation of full scale experimental treatment plants and by river studies.

The wastes selected for the investigations were obtained from a sole leather tannery using the vegetable tanning process, and located at Instanter, Pa.

LABORATORY STUDIES OF WASTES: The various kinds of wastes produced were measured and analyzed. It was found, for example, that while the vat wastes contributed three-quarters of the total putrescence, their volume was little more than one quarter of the total daily wastes.

Experiments to Find Possible Methods of Treatment: More than a thousand separate experiments were made and recorded. Broadly speaking, the objective was such a method of combining the various wastes, as would produce chemical reactions between themselves, and so obtain the maximum amount of self-purification. Further purification, by addition of chemicals, was studied.

FULL SCALE TESTING: As a result of the above experiments, which covered 20 months of laboratory work, a half dozen of the most promising methods of treatment were selected for testing at full scale.

Instanter Experimental Plant: In the spring of 1926 a full scale experimental treatment plant was constructed at the Instanter Tannery of the Elk Tanning Co. It was situated on the East Branch of the Clarion River, unpolluted except by the tannery from its source to a point 12 miles downstream. This made an ideal condition for studies of the actual effect of various treatments on the river waters.

The selected treatments were experimented with here during the summer and fall of 1926. The purified wastes and the sludges (the material caused to settle out of the wastes) were analyzed in the laboratory and studied. All operating data such as volumes of wastes, of sludges, chemicals required, etc., were collected. Several

men were constantly employed at the plant to operate it and collect samples. Two schemes of treatment stood out as best after these tests and studies. They have since been thoroughly tried, and the one finally outstanding is described on pp. 22-24.

RIVER STUDIES: The manner in which the various full scale treatments affected the receiving stream was determined by analyzing the river water at certain places along the 12 miles of stream below the tannery. It was shown that the self-purifying power of the stream was marked. In the future it may become possible to forecast the effect of any waste on any river. In the fall of 1926, however, the tannery at Instanter was compelled to shut down, so that the experimental plant had to be dismantled. A second full scale experimental plant was constructed at Emporium, but nearby the creek received the town sewage as well as the wastes from the tannery, and the Committee decided to attempt no further stream studies.

FULL SCALE EXPERIMENTAL TANNERY WASTE TREATMENT PLANT AT EMPORIUM

During the winter of 1926-27 the Engineering Bureau of the Pennsylvania Department of Health, after surveys and consultations with the engineers and chemists of the Committee, prepared plans for a full scale plant embodying the principles then developed. The design permitted many variations in treatment to be carried forward in steps, the results of each being carefully studied at the plant and in the laboratory.

The EMPORIUM FULL SCALE PLANT (of which Figure O, p. 18, is a profile diagram) consisted of:

A system of troughs which brought the wastes by gravity from the tannery to a sump. Two electric centrifugal pumps, controlled by float-operated automatic switches, drawing from this sump. Two elevated wood-stave settling tanks (marked A1 and A2 in Fig. O); an elevated equalizing tank (marked C); and the precipitation tank (B). The tanks and sump had a combined effective capacity of 195,000 gallons. All tanks were provided with means for sludge removal.

There was also an operating platform where chemical feeding and flow regulating devices were located, and six cinder sludge-drying beds occupying altogether about one-third of an acre. The beds were underdrained with farm tile. Sewers, pumping mains, sludge removal valves and troughs, an acid feed line, steam lines for heating, a compressed air pump, and electric lights were installed. A good deal of small experimental apparatus was constructed, not shown in the diagram.

The foregoing parts of the Emporium plant were built in 1927. There were later added a second 16,500 gallon C-tank (not shown) to permit of 16-hour operation instead of the 8 originally intended; a 33½ foot diameter, 6 foot deep trickling filter unit (marked F), and a number of shallow basins for settling the filter effluent.

The cost of such a plant as this, new and complete, is estimated at $29,500—without filters or final basins, $22,500. These figures are based on Emporium construction cost data.

Certain details of the apparatus listed above, and its operation, may warrant further mention.

The *precipitation tank* (B in Fig. O) is shown also in Fig. 1 (p. 19). It was in effect a long, narrow, deep tank, coiled up. The wastes, entering at the center, followed a spiral path to the discharge weir in the outer compartment. Tank B removed an average of 82% of the suspended matter from the coagulated wastes. It was found that sludge valves must be located in the floor of the tank at about 4-foot intervals. This permitted satisfactory sludge removal without draining the tank or interfering with its operation. A suggested arrangement of flap valves, for discharging the sludge to the drying beds, via troughs under the tank, is indicated in Figure 1.

The *flap valves* themselves are of cast iron. They are relatively cheap and remarkably sludge-tight when closed. Working drawings comprise Figure 2, p. 19.

A useful *mixing box*, a small tank with baffles so arranged that the wastes in flowing through tumble and churn very thoroughly, is shown in Figure 3, p. 19. It is used for causing the chemicals, added for coagulation of the wastes, to mix and react with them completely.

Sludge-drying Beds: A typical cross section as used at Emporium is shown in Figure 5, p. 19. The cost of replacing the fine surface cinders over such large areas was something of an item,—over $3.00 per month per bed. For this reason the design shown in Figure 6 is suggested. Such beds would probably drain nearly as well as the Figure 5 type, but the cinder area being less the maintenance as well as the construction cost would be smaller.

The sludge beds were each underdrained by a line of 4″ farm tile. A 6″ collector drain carried the drainage via a manhole and existing sewer to the stream, until it was found that a certain amount of "thin" sludge was passing through the cinders and so into the stream. A return drain was then laid which carried the sludge drainage back to the sump for retreatment. Its volume was not great enough to have any marked effect on waste treatment or total sludge volumes, but its discharge to the stream was not permissible.

A drain leading only to the sump is recommended for any future plant using underdrained sludge drying beds.

Swivel, or skimmer, pipes for conveniently removing the top water from the sludge beds were installed. They led directly into the underdrains. After the sludges began to dry, but before cracking occurred, the surface was quite impervious and held rain water. The swivel drain made it easy to remove this without opening channels in the sludge with shovels.

Full scale experimental filter unit: ("F" in Fig. O, p. 18). This was built after careful preliminary studies. It was designed as a full

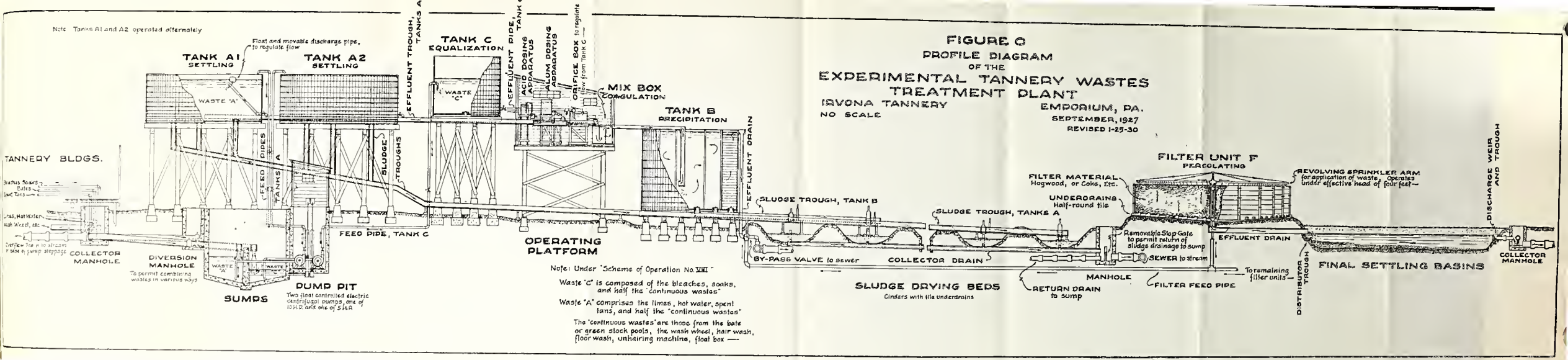
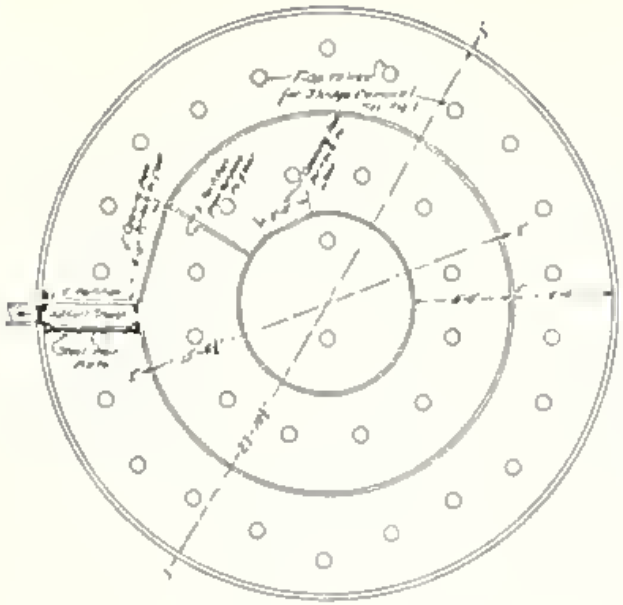


FIGURE C
PROFILE DIAGRAM
OF THE
EXPERIMENTAL TANNERY WASTES
TREATMENT PLANT
IRVONA TANNERY
EMPORIUM, PA.
NO SCALE
SEPTEMBER, 1927
REVISED 1-25-30
Note Tanks A1 and A2 operated alternately
Float and movable discharge pipe, to regulate flow
TANK A1
SETTLING
TANK A2
SETTLING
WASTE "A"
EFFLUENT TROUGH, TANKS A
TANK C
EQUALIZATION
WASTE "C"
EFFLUENT PIPE, TANK C
ACID DOSING APPARATUS
ALUM DOSING APPARATUS
ORIFICE BOX to regulate flow from Tank C
MIX BOX
COAGULATION
TANK B
PRECIPITATION
EFFLUENT DRAIN
TANNERY BLDGS.
Bleaches Soaks
Bates
Lime Tans
Lime, Hot Water
Wash Wheel, etc.
Overflow line to stream
Lime in pump stoppage
COLLECTOR MANHOLE
DIVERSION MANHOLE
To permit combining wastes in various ways
FEED PIPES
TANKS A
SLUDGE TROUGHS
FEED PIPE, TANK C
OPERATING PLATFORM
SUMPS
DUMP PIT
Two float controlled electric centrifugal pumps, one of 10 H.P. and one of 5 H.P.
SLUDGE TROUGH, TANK B
SLUDGE TROUGH, TANKS A
BY-PASS VALVE to sewer
COLLECTOR DRAIN
SLUDGE DRYING BEDS
Cinders with tile underdrains
RETURN DRAIN to sump
MANHOLE
FILTER FEED PIPE
FILTER UNIT F
PERCOLATING
FILTER MATERIAL
Hogwood, or Coke, Etc.
UNDERDRAINS
Half-round tile
REVOLVING SPRINKLER ARM for application of waste, Operates under effective head of four feet
Removable Stop Gate to permit return of sludge drainage to sump
SEWER to stream
EFFLUENT DRAIN
To remaining filter units
DISTRIBUTOR TROUGH
FINAL SETTLING BASINS
DISCHARGE WEIR AND TROUGH
COLLECTOR MANHOLE
Note: Under "Scheme of Operation No. VIII"
Waste "C" is composed of the bleaches, soaks, and half the "continuous wastes"
Waste "A" comprises the limes, hot water, spent tans, and half the "continuous wastes"
The "continuous wastes" are those from the bate or green stock pools, the wash wheel, hair wash, floor wash, unhairing machine, float box —



Plan

Fig 1

Settling Tank B

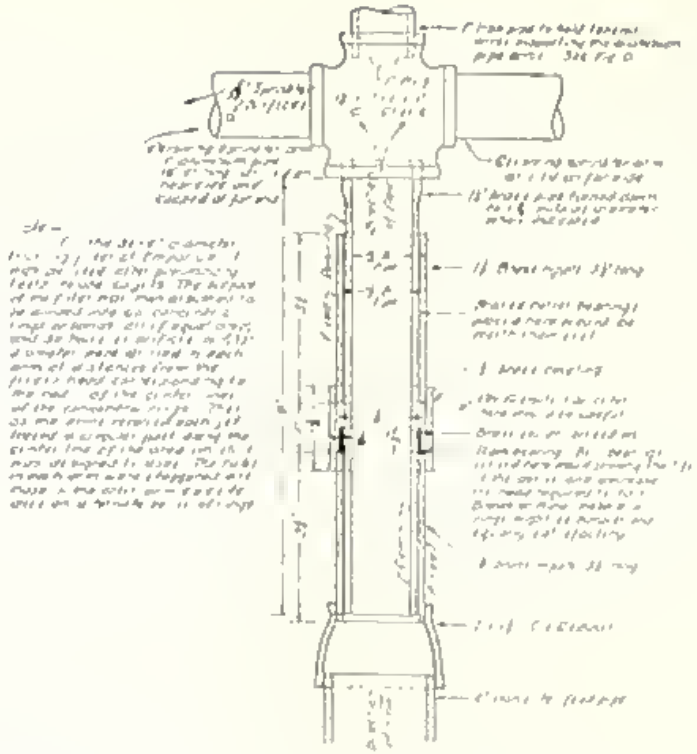


Fig 4

Revolving Sprinkler Head

See Fig 0 for small diagram of whole sprinkler system

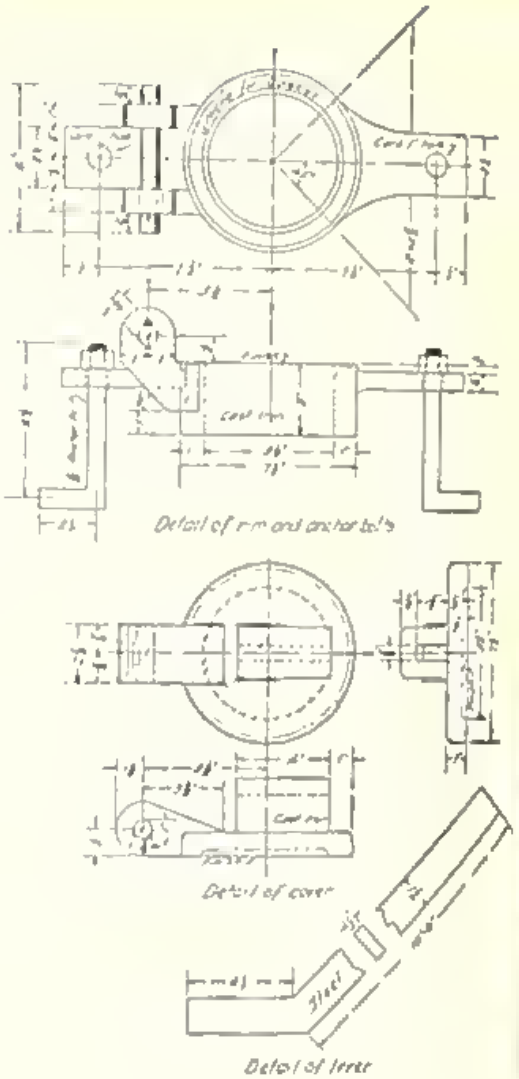


Fig. 2

Flap Valve for Sludge Removal

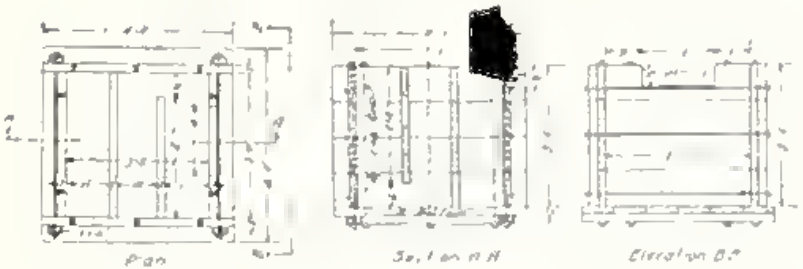


Fig 3

Mixing Box

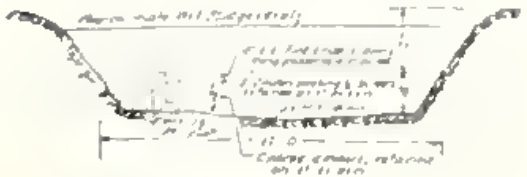


Fig 5

Emporium Sludge Beds, Cross Section

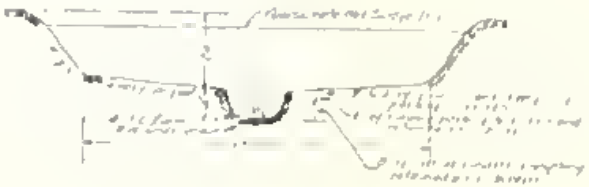


Fig 6

Suggested Sludge Beds, Cross Section

SPECIAL DEVICES AND STRUCTURES

Used at Experimental Waste Treatment Plant

Emporium Pa

1927 - 1930

scale unit in every respect, and was able to treat one-third of the daily volume of waste discharged by the Emporium tannery.

Filter F was polygonal in plan, about 33′ 6″ in diameter, with 6′ 6″ walls, and built of hemlock lumber. It was divided into eight equal compartments in which different filtering materials could be tested under full scale conditions. These included coke, several sorts of "hogwood" or wood chips varying from matchstick to clothespin size, slag, cinders, crushed tile, shavings and spent tank bark. The total cubic contents of the filter equalled 195 cu.yds. The floor sloped from two sides toward the center (like a circular sheet of paper creased down the middle) to a covered collector trough. The trough was divided into separate channels, one for each compartment.

Underdrainage was accomplished by means of inverted half-round tile, laid in parallel rows close together, with open joints. Short strips of lath were laid under the four corners of each length of tile to permit free drainage, and the spaces between the rows were filled with broken stone. The drainage flow took place along the floor, in the paths left open by the inverted half-round tile. The ends of the tile were carried through the filter walls to help ventilation and allow flushing.

The feed pipe for the revolving sprinkler arm which comprised the *dosing apparatus* rose through the center of the filter. The revolving arms were driven by the jets from numerous small holes, so placed as to give even distribution over the surface of the filter. At 1400 gallons per hour the revolving arm made about three revolutions per minute under a 7-foot head.

The Filter F dosing system was proved practicable for such trickling filters as may be required by tanneries in or near this latitude and comparatively cheap to construct. The revolving sprinkler head is shown in detail in Figure 4, p. 19.

Settling Basins for Filter Effluents: Secondary settling basins, each 2.75 feet wide by 27.5 feet long by 2 feet deep, were constructed for the filter effluents. They were shallow earthen lagoons. Swivel draw-down pipes for drawing the supernatant liquid from the sludge prior to cleaning the basins, also discharge weirs and a collecting drain for carrying the effluents from the basins to the main sewer, were provided. Conduits were built which distributed the inflowing wastes with fair uniformity across the width of the basins at their entrance ends, about 6 inches below the surface.

Discharge Line: The final plant effluent was discharged through an existing terra cotta sewer laid so that it dipped to form a steep grade near the stream. Therefore, although the discharge was submerged a foot or two, there was considerable foam in the effluent when it reached the stream, and this was carried down stream for some distance before it disapeared.

The discharge line should approach the stream at an easy grade, should be evenly laid with well wiped joints, and should also approach

the bank so as to discharge a smoothly flowing, foam-free effluent into the stream in the direction of its flow. The discharge should be submerged.

SMALL SCALE EXPERIMENTAL APPARATUS: This comprised numerous model filters, usually 5 feet in diameter and 6 to 15 feet deep, sludge liquefaction tanks, small model settling tanks, a tan drying tray, aerator, etc. etc.

ORGANIZATION OF THE EMPORIUM INVESTIGATORY WORK 1927-30

PLANT OPERATION for 16 to 24 hours per day was used because a given volume of waste, discharged evenly during that time, is much less harmful to a stream than the same waste discharged in 8 hours, and filter operation is more economical on a 22 to 24 hour per day basis.

TESTS: Numerous separate tests, over periods ranging from a few days to twelve months, were made. During tests, samples were collected hourly from various parts of the plant, to be shipped to the laboratory in batches for analysis.

LABORATORY ANALYSES: Samples were routinely analyzed to determine the total, soluble, suspended, volatile and fixed solids and the 5-day oxygen demand* in parts per million by weight.** The color values determined were those of the "true color" of the samples, that is, the color after the suspended matter had been removed. The "pH" was a measure of alkalinity, or acidity. Bacterial counts were made on certain samples.

All these determinations were made according to the procedure sponsored by the American Public Health Association and the American Water Works Association and published in the 1925 edition of "Standard Methods for the Examination of Water and Sewage."

REPORTS: All possible data, such as quantities, behavior of the apparatus, desirable alterations, labor and power required, were noted in writing by the men at the plant. Analytical results were computed and tabulated at the laboratory. All this information was assembled by the engineer in charge and submitted to the committee at its regular meetings with description, comment and recommendations.*** These reports totalled nearly 400 typewritten pages with tables.

The whole of the Emporium studies may be found described in detail in a typed report of about 200 pages and in a separately bound volume of 75 tables, containing the results of 5000 to 6000 sets of analyses. Each set involved nine separate determinations (one of which required the incubation for a five day period of a portion of the sample) so that about 50,000 analytical determinations are collected in the above volume of tables, in addition to other general data, summary sheets and charts.

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* Generally written "5-day O.D." A measure of polluting power.
** Generally written "P.P.M."
*** Operating Reports, December, 1927 to April, 1930.

In this connection it is to be noted that the Instanter investigations (1925-27) were chronicled in about 75 pages of periodic reports and in a complete report of 250 pages of text and tables.

The present paper presents in a very condensed form some of the most essential parts of the voluminous data contained in the above mentioned records.

AVERAGE QUANTITIES, AND ANALYSES OF WASTES AT THE EMPORIUM TANNERY

The tannery at Emporium was typical and middle-sized. Based on daily records, an average total of about 80,500 gallons of waste was discharged daily during the period of operation of the Emporium experimental plant. During this period the tannery operated at 84% average capacity. The wastes were practically equivalent to those produced at the full capacity of 13,500 pounds of green salted hides per day.

The approximate quantities of the several wastes produced by the tannery are given below:

INDIVIDUAL WASTES AT EMPORIUM

Tannery Operating at Average 84% Capacity		Approximate Percentages of the Total Oxygen Demand**
Kinds of Waste	Gallons Per Day	
*Soaks	10,000	5%
*Limes	3,200	10
*Hot Water	8,000	5
Unhairing Machine	1,600	1
Wash Wheel	24,000	15
Float Box	900	0
Bate Pools	9,000	1
Hair Wash	14,100	5
Floor Wash	2,200	1
*Spent Tan Liquor	4,800	50
*Strong Acid Bleach †	675	2
*Weak Acid Bleach	1,350	2
*Soda Bleach †	675	3
Approx. Av. Totals	80,500	100
Totals of "Intermittent" Wastes	28,760	77
Totals of "Continuous" Wastes	51,800	23

* Designated by this Committee as "Intermittent" wastes. Those not starred are called "Continuous" wastes.
** Oxygen Demand—See page 9.
† Usually, 1350 gal. discharged on alternate days.

The intermittent wastes are generally less than 40% of the total wastes in volume, yet are responsible for over 75% of the total 5-day oxygen demand. These percentages represent average data for several tanneries.

The difficulty of treating tannery waste is largely due to the spent tan liquor. At Emporium it contributed half the polluting power of the raw waste and, with the bleach wastes, almost all the color, yet it formed only about 6% by volume of the total. The bleach wastes, small as they were in volume, contributed 5 to 10% of the polluting power.

Because of the difficulty of treatment caused by the spent tan liquors and bleaches, it is suggested that arrangements be made, if such be

required, at all tanneries to insure the discharge of approximately uniform quantities of these wastes from day to day. This can usually be accomplished by utilizing several idle tan yard vats as storage tanks. At Emporium the daily quantity of spent tan liquor varied from double the normal to nothing, causing great daily variation in the quality of the final treated wastes.

Analyses of Combined Raw Wastes: Small beakers of waste were collected at half minute intervals from the pumping lines at their points of discharge into the tanks and mixed to form a composite for the day, a portion of this being analyzed. The averages of several important characteristics are as follows:

ANALYSES OF COMBINED RAW WASTES

	Suspended Solids	Color*	pH+	5-Day O. D.°
	Parts Per Million, By Weight	A. P. H. A.		Parts Per Million By Weight
General Average, 254 days' samples	2523	3520	11.3	1030

STUDIES OF METHODS OF WASTE TREATMENT WITHOUT FILTRATION

The scientific principles upon which the design of the Emporium plant was based, are sound. Tests were made to confirm the Instanter results, to determine such modifications as might prove necessary, and to develop other methods of treatment to meet as far as possible the requirement of lower operating cost. Nineteen separate tests were made at full scale, over periods ranging from a few days to fourteen months.

Most operating studies were necessarily lengthy. Daily wastes varied greatly in strength and amount, and any important innovation had to be tested for two weeks (better two months) before its value could be determined. Final judgment had to be based on a study of all data afforded by the tests, the collection of which involved much painstaking routine work. Yet this is the only road to the final solution of the whole problem of waste disposal; there is no cure-all.

TREATMENT USING CHEMICAL COAGULATION WITHOUT FILTRATION: The Emporium plant (Fig. O, p. 18) was flexible enough to permit tests under full scale conditions of a number of widely differing schemes of treatment. *The scheme for which the plant was chiefly designed,*** and the essentials of which were developed by the Instanter investigations, was as follows:

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* Color by American Public Health Association standards.
+ Here, a measure of alkalinity.
° Here, a measure of oxygen-consuming power, or putrescibility.
** Designated "Scheme VIII" during the course of the experimental work, in reports, figures and tables. Cf. page 33 and Figure O. p. 18.

The wastes from the lime, tan and "bleach" vats, plus one-half the wash waters, were drained to one side of the sump and pumped into large tanks* 15 feet about the ground where they were allowed to settle quietly overnight. The settled material was called sludge.

The wastes from the soak vats, plus the other half of the wash waters, were drained to the other side of the sump and pumped to an elevated equalizing tank+ whence they flowed at an even rate to the operating platform; there they were mixed at an even rate with the settled liquid drawn from the aforementioned large tanks.

On the operating platform the combined wastes were treated with acid and alum, applied at even rates during 16 to 24 hours per day. These together caused most of the remaining suspended material to settle out as sludge, lightened the color considerably, and reduced the oxygen demand somewhat. This took place in a "precipitation" tank++ through which the wastes flowed very slowly to the outfall, whence they could be discharged to the sewer and thence to the stream. About 18 grains of alum** per gallon of wastes to be coagulated seemed to be the proper quantity.

In coagulation with alum, the wastes must have a certain degree of acidity.*** If the alum itself is not sufficient to produce this, an acid—usually sulphuric acid—must be added. (If the wastes happen to be too acid, however, lime must be added). The alum then forms a "floc," or flake, which as it is formed decolorizes the wastes and as it settles coagulates or carries down with it most of the tiny particles of suspended matter.

Results: This scheme is referred to in Table A (p. 34) as a *"Special Plan of Waste Treatment."* Percentages of improvement of the wastes are given, as well as costs. Where a high percentage of settleable material must be removed and the color appreciably lightened, but where the oxygen demand reduction need not be greater than about 50 per cent, this scheme seemed suitable.

Where considerable all-around improvement is required, chemical coagulation is more economical as well as more effective when applied after filtration. This is illustrated by the figures in Table A and in Table B (p. 35).

A slight *modification of the above*, suitable for use where similar results were required, consisted in giving preliminary settlement to the wastes from the lime vats before mixing them with the other wastes. This was adapted to the treatment of highly alkaline wastes, and lessened the amount of acid required for chemical treatment. The reduction in oxygen demand or polluting power was generally improved.

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* Marked "A" in Fig. O, p. 18.
\+ Marked "C" in Fig. O, p. 18.
++ Marked "B" in Fig. O, p. 18.
** More success was had with alum (aluminum sulphate) than with any other standard coagulant during the earlier tests at Emporium. Ferrous sulphate plus lime, in tests during Sept. 1930, appeared worth a trial at any tannery requiring chemical coagulation. About 10 grains to the gallon of wastes gave good results, with lime as required to produce a "floc", especially when applied to the coke filter effluent. The results in that case were better than those obtained with alum.
*** Technically, the wastes must have a pH value between 5 and 6.

Another method of treatment using chemical coagulation without filtration consists of a general mixture of all the raw wastes, settlement, chemical coagulation, and final settlement. A possible form of plant for this scheme of treatment is illustrated in plan and profile in Figure 7, p. 24, by the lower diagrams labelled "Special Plan of Waste Treatment." The results are about the same as for the previous schemes, but more tank capacity is required. This would be an item where concrete or elevated wood stave tanks were used, but for earthen basins the scheme is feasible and has the advantage of simplicity and of ready adaptability to treatment without chemical coagulation whenever this may be permissible, as during periods of high water.

General averages of the percentages of reduction in the most objectionable characteristics of the raw wastes are given in Table A, p. 27. The coagulated and settled wastes were reasonably clear and about the color of weak tea.

Sludges were withdrawn from all tanks periodically and discharged upon drying beds.

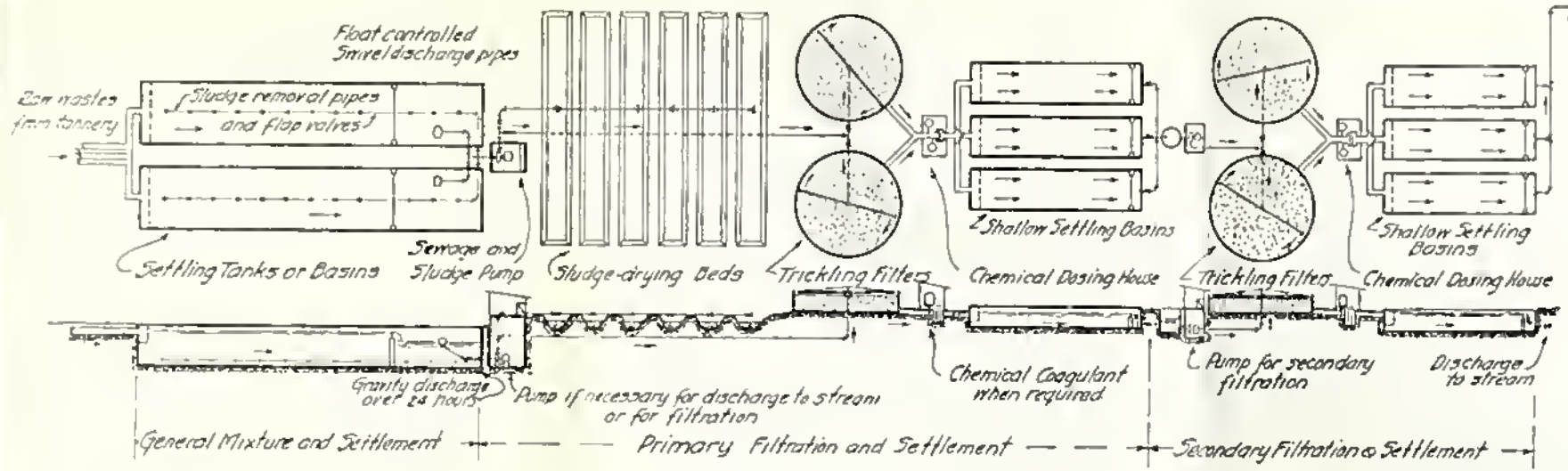
Numerous tests, which occupied altogether nearly two years, were made of the above methods of treatment and variations of them, but the high cost of chemical coagulation and the small improvement obtained therewith in relation to the cost, except in color reduction, made essential the study of other methods of treatment.

TREATMENT WITHOUT CHEMICAL COAGULATION BEFORE FILTRATION: After long preliminary tests, a *simplified scheme* was developed consisting of the general mixture of all raw wastes, thorough settlement, and even discharge of the settled liquid over 24 hours. This gave somewhat better results, where coagulation was not used, than any other method of treatment. It seems most suitable for general use, based on 11 months' testing, and forms the first step of the *General Plan of Waste Treatment.* A possible form of plant is shown in plan and profile in the upper diagrams of Figure 7, p. 24. Percentages of improvement obtainable in the waste are given in Table A, p. 27, with the cost.

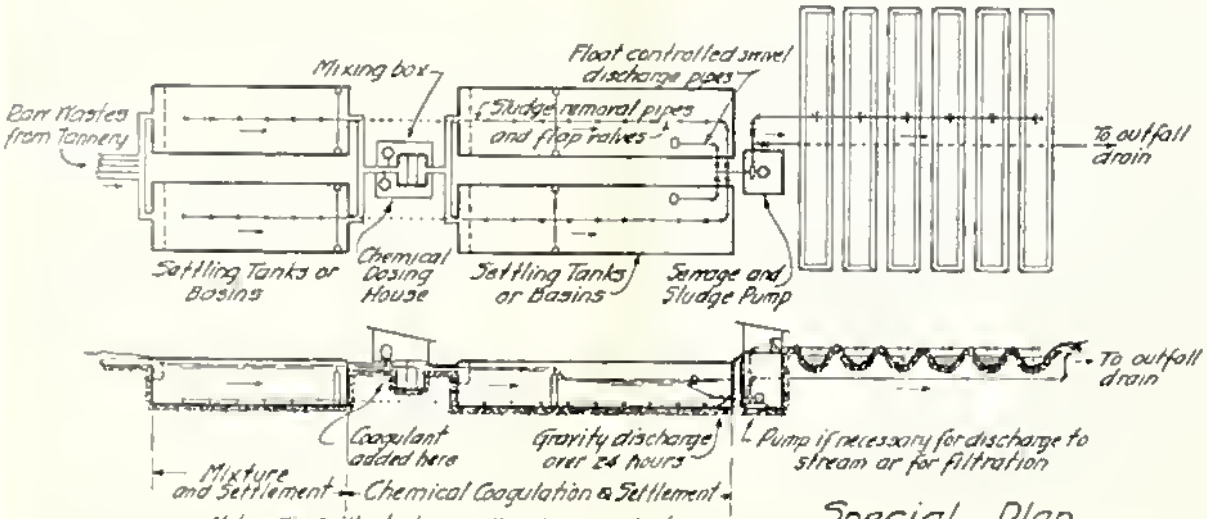
Considering the difference in cost, remarkable results are obtained without chemical coagulation in the "first step" of the general plan of treatment, as compared with the first step of the special plan. The color of the settled wastes was about that of strong tea. Brief descriptions of these plans are given on pages 13 and 14. They are outlined in more detail on pages 26 to 30. Summaries are given on pages 34 to 36. The purification accomplished by the foregoing treatments of the wastes averaged only 50% with chemical treatment and about 40% without it. Further steps were required for complete treatment. The most satisfactory of such steps proved to be trickling filtration.

STUDIES OF WASTE TREATMENT BY FILTRATION

The results of over two years of study with small scale and full scale units indicated that more economical results in further improvement could be obtained with trickling filtration through coke or wood chips than by any other means yet tried.



GENERAL PLAN



Note - Fig. 0 illustrates another form of plant based on the Special Plan

Special Plan

Where considerable all-around improvement is required, chemical coagulation is more economical as well as more effective when applied after filtration (either primary or secondary) as in the General Plan above.

FIGURE 7

TREATMENT PLANT DIAGRAMS

Based Upon Studies By The

TANNERY WASTE DISPOSAL COMMITTEE OF PA.

The term "*trickling filtration,*" as applied to sewage and waste treatment, does not mean the passage of the wastes through a strainer. They are sprayed as steadily and uniformly as possible over the top of a rather deep bed (very well drained and ventilated) of coarse material, and allowed to trickle slowly in a thin film over the surfaces of each piece of the "filtering" material. In this way the oxygen of the air has access to the decayable matter in the wastes and can oxidize it, reducing the objectionable "oxygen demand." Also, certain forms of bacteria tend to collect on the surfaces of the filter material and help in the work of purification. Suspended material should not be retained in a trickling filter; if it is so retained the filter will clog. This clogging, however, does occur with tannery waste and seems unavoidable; therefore, the cost of filtration as given includes the replacement cost of the coke or other material at intervals as noted on the estimate sheets, pp. 32 and 33.

FULL SCALE TRICKLING FILTER UNIT: After a year of experiment with model filters, and using the knowledge gained therefrom, a simple, practicable type of trickling filter was developed for the treatment of tannery waste after settling; and a full scale filter unit (described on pp. 18 and 19, marked F in Fig. O, p. 18) was constructed. Experiments indicated that *22 to 24 hour per day operation* was the most practical as well as the most desirable operating time. No serious trouble was experienced during *winter operation* in central Pennsylvania. The formation of rings of ice on the surface of the filter between the jet paths was controlled and prevented from reaching the height of the arms by admitting steam for an hour or so to the filter feed pipe. This method, being needed only occasionally during a season, should not prove costly even for a very severe winter.

PRIMARY FILTRATION: For 3 months the coagulated and settled wastes, the product of the first step under the "special plan" of waste treatment (cf. Table A, p. 27), were filtered in the full scale experimental filter. For the subsequent 10 months the filter was dosed with the wastes discharged after mixing and plain settlement as under the first step of the "general plan" of treatment (Table A). Filtration thus formed the "*Second Step*" of treatment under either plan, although a study of results *vs.* costs indicates that under the special plan it is probably not economical.

Primary filters are shown in the diagrams, Figures O, p. 18, and 7, p. 24.

Rates of dosing between 1¼ and 1½ million gallons per acre per day* seemed to be about the most favorable. Daily variations in *waste volumes* at Emporium were considerable, but were due almost entirely to variations in the quantities of wash waters. Therefore, if the volume of the combined wastes was large the filter could properly be dosed more heavily since the wastes were more dilute; if the volume was smaller than average the filter could properly be dosed more lightly, since the wastes were more concentrated.

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* This equals 25,000 to 30,000 gallons per day for Filter F. Three units similar to Filter F would have been required to treat the maximum volume of Emporium wastes.

Twelve different "filtering" materials were tested at full scale, at various rates, and for 12 to 24 hours per day. When the particles were too small, as in spent tan bark or shavings, a material clogged very soon; when the pieces were too coarse, as in broken tile, there was little reduction in oxygen demand. This was also true of the very fine material, which became saturated with liquid and excluded the air. The best results were obtained with moderate sized material such as the coke, the lumps being from ¾″ to 1½″ in diameter, or the hogwood, which consisted of wood chips from matchstick to clothes-pin size.

The wastes, when made slightly acid by alum coagulation, were turned blue-black by any material such as cinders, which contained much iron. When the wastes were uncoagulated, and hence alkaline, this did not occur.

The coke used at Emporium gave a blue-black color only to the acidified wastes when first used; the hogwood never. All wastes were turned a darker brown by the partial oxidation occurring in the filter.

After about 9 months' use several materials began to clog, notably the hogwood, and to lose efficiency in purifying the wastes. During 14 months of use the coke gave no signs of clogging. This *clogging* at Emporium seemed to be due to a deposit of limy material from the alkaline wastes on the surfaces of the filter material. The deposit formed very slowly on the coke, but quite rapidly on the hogwood. Possibly coke would be more satisfactory for tanneries with highly alkaline wastes, and hogwood for those with only slightly alkaline or with chemically coagulated wastes. Filtration through coke generally turns the wastes a darker brown than does hogwood.

The principal effects of filtration seem to be: to coagulate suspended or colloidal matter so that it can be removed in settling basins, to decrease the alkalinity, and to oxidize. Oxidation reduces the 5-day O. D. and (short of very complete oxidation) increases the color.

The *cost* of waste treatment by filtration is slightly lower per unit percent of reduction in oxygen demand, than by any other method of treatment. Cf. Table B.

Of course, *sufficient storage capacity* must be provided to allow for 22 to 24 hours feeding of the settled wastes to the filters at any plant which may use them; but since 24 hour distribution of the discharge to the stream is a step in treatment which would almost if not invariably be taken before filtration was resorted to, it may be assumed that sufficient storage capacity will exist or be in process of construction wherever filters are built.

Settlement after Primary Filtration: This was a part of the second step in treatment.

Shallow earthen basins were used, described on p. 19. The filter effluents flowed by gravity directly to these basins, which seemed to require cleaning once each month. The sludge was removed by pumping and discharged on a cinder sludge-drying bed. The average re-

TABLE A — Average Percentages of Reduction, in Round Figures, from the Raw Wastes Based on Full Scale Tests at Emporium, Pa

Description	FIRST STEP			SECOND STEP			THIRD STEP		
	Suspended Solids	Color	5-Day Oxygen Demand	Suspended Solids	Color	5 Day Oxygen Demand	Suspended Solids	Color	5-Day Oxygen Demand
GENERAL PLAN of WASTE TREATMENT (cf text, page 31)	Effect of General Mixture of Wastes and Plain Settlement			Effect of First Step plus Primary Filtration* and Settlement			Effect of First & Second Steps plus Secondary Filtration and** Final Settlement		
Analytical Data ------	80 to 90%	30% Incr to 50% Redn	25 to 50%	85 to 95%	30% Incr to 35% Redn	55 to 80%	90 to 99%	30% Incr to 40% Redn	75 to 90%
For Emporium, capacity 3500 lb raw hide per day. The cost per 100 lb leather (if 100 lb raw hide is equivalent to 70 lbs leather) cf text p 29	Av 85%	Av 6% Redn	Av 41%	Av 93%	Av 15% Redn	Av 68%	Av 98%	Av 8% Redn	Av 85%
	8 Cents (Total Operating Cost)			8¢ (First Step) + 5¢ (Second Step) = 13 Cents (Total Operating Cost)			8¢ (1st Step) + 5¢ (2nd Step) + 3½¢ (3rd Step) = 16½ Cents (Total Operating Cost)		
SPECIAL PLAN of WASTE TREATMENT (cf text pages 31 & 32)	Effect of Combination of Certain Stages, Plus Chemical Coagulation and Settlement			△ Effect of First Step Plus Filtration and Settlement			Where considerable all-around improvement is required, chemical coagulation is more economical as well as more effective when applied after filtration (either primary or secondary) as in the general plan above		
Analytical Data ------	95 to 98%	20 to 80%	25 to 70%	95 to 99%	0 to 50%	80 to 90%			
For Emporium capacity 3500 lb raw hide per day. The cost per 100 lbs leather (if 100 lbs raw hide is equivalent to 70 lbs leather) cf text p 29	Av 97%	Av 50%	Av 50%	Av 98%	Av 28%	Av 89%			
	23 Cents (Total Operating Cost)			23¢ (1st Step) + 5¢ (2nd Step) = 28 Cents (Total Operating Cost)					

* INTERMEDIATE STEP "A"
The estimated effect of chemical coagulation at this point applying the coagulant to the filter effluent at the settling basin entrance, was as shown here
Operating cost per 100 lb leather, cf text p 29 →

Reductions from Raw Wastes

Suspended Solids	Color	5 Day O D
95±%	25 to 55%	75 to 85%
Av 95%	Av 35±%	Av 80±%

8¢ (1st Step) + 5¢ (2nd Step) + 13¢ (Intermediate Step) = 26 Cents (Total)

** INTERMEDIATE STEP "B"
The estimated effect of chemical coagulation at this point, the coagulant being applied to the filter effluent at the settling basin entrance, was as shown here
Operating cost per 100 lb leather, cf text p 29 →

Reductions from Raw Wastes

Suspended Solids	Color	5-Day O D
99±%	35 to 60%	85 to 91%
Av 98%	Av 45%	Av 88±%

8¢ (1st Step) + 5¢ (2nd Step) + 3½¢ (3rd Step) + 12½¢ (Intermediate Step) = 29 Cents (Total)

△ These figures are given for information only. It is not likely that primary filtration will be used to follow chemical coagulation and settlement, since, as the figures indicate, the results are hardly commensurate with the cost

sults indicate that about half the remaining suspended material is generally removed, the color slightly lightened, and the oxygen demand somewhat reduced by passage through the basins.

These basins should be built in groups of two or three for convenience in operation and cleaning, and are illustrated in Fig. O, p. 18 and Fig. 7, p. 24. Basins relatively somewhat larger and deeper, with lengths four or five times their widths, are recommended.

CHEMICAL COAGULATION can be used when required, forming an intermediate step in treatment. The dose of coagulant (alum, lime, lime plus alum or ferrous sulphate, etc.) is added at the point of discharge from the filter. Settlement is then obtained in the basins. The effect is shown in Table A, p. 27, part of the first footnote, marked thus (*) ; also in Table B, p. 37. The principal average improvements are in color and oxygen demand. The cost is relatively low, especially if only required for a few months each year.

These results are based on fewer and shorter tests than other results under the first and second steps, but should be approximately correct.

SECONDARY FILTRATION AND SETTLEMENT: As a *third step* in waste treatment, filtration through a second battery of filters, followed by settling basins, seems most satisfactory. A possible arrangement is illustrated in Fig. 7, p. 24.

Model Filters, 5 feet in diameter and containing a six-foot depth of hogwood, were used for tests of secondary filtration. A portion of the wastes, following the second step in treatment but without chemical coagulation were pumped through a small feed pipe and dosed, by means of small revolving sprinkler arms, upon the model filters. The secondary filter effluent flowed through small final settling basins. The results are given in Table A, p. 27.

CHEMICAL COAGULATION at the entrance to the final settling basins provides another intermediate step in treatment. Estimated results are given in the footnote marked thus (**) in Table A; also in Table B, p. 37.

Hogwood will probably be feasible for secondary filtration because much of the clogging lime is removed together with other particles in the primary filter and settling basins, i.e., by the second step in treatment. Hogwood, if its life and efficiency in oxygen demand reduction were equal to that of coke, would be cheaper. It would also be better, because, as previously noted, it darkens the wastes less than coke. No long-time tests of hogwood for secondary filtration were made at Emporium, so its life can only be estimated.

MISCELLANEOUS TESTS: In addition to the principal tests, discussed in the preceding pages, continual experiments were carried on in the laboratory and with model apparatus at the plant. Some effort was expended in attempts to ascertain the *part played by bacteria in the action of the filters*. Bacterial counts, microscopic examinations and other studies were made. The conclusion reached is that they do have a desirable but quite minor effect. Many gave negative re-

sults, and a few looked promising. All such tests are described in the General Reports covering the work of this Committee from 1924 to 1930.

SLUDGE DATA

Experimental Plant, Emporium, Pa.

Each sludge-drying bed* consisted of a 12″ layer of cinders retained on a 1″ screen, topped by a 2″ layer passing the 1″ but retained on a ½″ screen, topped again by a 2″ to 4″ layer of cinders—everything that passed a 1″ screen. A layer of these about ½″ thick adhered to the sludge and was removed at each cleaning. Surface cinders had to be replaced after about four cleanings.

The sludge beds were each underdrained by a single line of 4″ farm tile, laid with ¼″ open joints at a 0.5% grade.

Approximate data follows for sludges produced from 80,500 gallons of raw tannery wastes when chemical coagulation is used in pre-filtration treatment:

Sludge from settling tanks	7100 gal. per day	
Sludge from settling basins for filter effluents	200 " " "	
Total	7300 " " "	or about 9% of average total volume of raw wastes.

Average volume of wet sludge per pound of leather, 0.77 gallons.

Average dosage, and drying time, wet to dry sludge:

Winter, beds dosed 14″ to 18″ deep, 1 to 3 weeks, depending on weather.

Summer, beds dosed 16″ to 20″ deep, 1 to 2 weeks.

Approximate reduction in volume, wet to dry:

Between 70% and 85%.

Estimated number of beds required (allow depth of 18 inches for cinders and 24 inches for sludge—see Fig. 5, p. 19):

Nine beds, 12 ft. x 100 ft. Equivalent to 1.14 sq. ft. drying bed surface per *pound of leather per day.*

Average labor for sludge removal (shovels and wheelbarrows) *and piling nearby:*

All sludges: 16 cu. ft. dried sludge per man-hour.

Average moisture content:

Wet—92% to 98% dry enough for removal, 80% to 90%.

Average organic content: Wet, 1% to 3%; dry, 6% to 9%.

Average ash content: Wet, 1″ to 5%; dry, 4% to 11%.

* See also page 18.

Sludge seems to handle best when about the consistency of gelatine, or at about 85% moisture. It is impossible to get much better drying than this in cold or very wet weather, and seems uneconomical except during the summer months, when the sludge can be allowed to dry to 75% or 80% moisture.

Final Disposal of Dried Sludge: The sludge has a certain fertilizing value—not very great. Local farmers carted away about half the dried sludge from the full scale plant. Except for this, the sludge was used for filling low ground near the tannery.

For a general mixture of all raw wastes (80,500 gallons), quiet overnight settlement and withdrawal of supernatant liquid during 21 hours, the approximate sludge volumes were:

Wet sludge from settled raw wastes:	3600 gal. per day
Wet sludge from settling basins for filter effluent	400 " " "
Total	4000 " " " or about 5% of the average total volume of raw wastes

Average volume of wet sludge per pound of leather, 0.42 gallons.

Approximate average moisture content: Wet, 95%; dry, 85%

Approximate average organic content: Wet, 2%; dry, 6%.

Approximate average ash content: Wet, 3%; dry, 9%

Other data as above except that a total of only 6 beds should be required. This is equivalent to 0.76 sq. ft. drying bed surface per pound of leather per day.

Tests of mechanical sludge-drying were made by manufacturers of sludge-drying equipment. This method is relatively costly, but might be applicable to certain tanneries, such as those located in closely built-up sections.

ESTIMATES OF COSTS OF TREATMENT as given in succeeding pages are based on the Emporium plant and conditions, and represent estimated costs for treatments applied continuously throughout the year. Actual yearly costs for the average tannery are likely to be lower.

A LIST OF FACTORS tending to modify Emporium costs for many tanneries:

(1) More economically arranged treatment plants.

(2) Larger plants handling wastes from many more hides than at Emporium with some decrease in operating and investment costs.

(3) The almost inevitable curbing of excessive use of water in the tanning process. The average American tannery uses 400

gallons of water per hide per day. Emporium averaged this, but the average in Europe is nearer 100 gallons.

(4) The probability that the average chemical cost will be lower than at Emporium, since the wastes from most tanneries are less strongly alkaline.

(5) The likelihood that all types of treatment can be modified during winter and spring.

These and similar considerations make it likely that the actual average yearly cost of treatment will prove less than at the experimental plant.

It is also true that the added burden produced by the methods of waste treatment developed at Emporium will be the difference between the cost of the new treatment and of the partial treatments already in use. These later certainly form a part of the present cost of leather production.

For summaries of costs, see pages 32 to 34, also Tables A, p. 27, and B, p. 37.

COST DATA

Treatment Plant for Wastes from a Sole Leather Tannery of 13,500 lb. Green Hide Per Day Capacity (Vegetable Tanning)

Estimated Cost of a New and Complete Plant (For Combination of Certain Wastes Plus Chemical Coagulation and Settlement) *8-hour Discharge Period.*

Actual cost of plant as originally erected at Emporium ... (Designed for Scheme VIII*, 8-hour discharge period, and some existing structures, as the sump, utilized. Only 6 sludge-drying beds, of 1200 sq. ft. each, provided.)	$ 15,400
Extra cost of reconstructed sludge beds if built new, say .	100
Additional sludge beds (3 of 1200 sq. ft. each required) ..	1,050
Additional cost of Precipitation Tank B if received new ..	1,200
Cost of existing concrete sump if built new	1,000
Extra cost of Settling Tanks A if built of entirely new material	550
	$ 19,300
Engineering and contingencies, 10%, say	2,000
Total	$ 21,300
If Plant is Constructed for BD-*hour Discharge Period*	
Estimated extra cost for larger equalization and storage tank	1,200
	$ 22,500

* See p. 22, sixth paragraph, et seq., and Fig. O, p. 18.

If Filtration Is Used:

Estimated cost of one Filter Unit (with final settling basin):

Structure	$ 600	
Dosing apparatus	50	
Fill, paint, etc.	100	
Filter material, screened coke, ¾″ to 1½″	800**	
Final settling basins	325	
	1,875	
Contingencies, 10%, say	190	
	$ 2,065	
For Emporium, 3 units required, cost say		$ 6,200
1 extra sludge bed		350
1 sludge pump and incidentals		450
		$ 29,500

ITEMIZED ESTIMATES OF COSTS OF PLANT OPERATION

Fixed charges not a part of these actual operating charges.

COSTS OF TREATMENT PRIOR TO FILTRATION

Without Chemical Coagulation No Filtration		*With Chemical Coagulation No Filtration*	
Operator: 1 man, 3 hours per day for 307 days, at 50 cents per hour	$ 460	1 man, 307 days at $4.00 per day	$1,230
		Chemicals, 307 days at $8.25	2,535
Electric power—12 mo. at 775 KWH at 3½ cents	325		325
Sludge handling	1,080		2,060
Replace fine cinders on sludge beds, (6 beds) at $3.25 p. bed p. mo.	235	(9 beds)	350
Steam (heating, thawing valves)	100		100
Incidental maintenance (paint, etc.)	100		100
Estimated yearly cost of plant operation	$2,300		$6,700

COST OF PRIMARY FILTRATION THROUGH TRICKLING FILTER
(Either with or without chemical treatment before filtration)

Including cost of handling sludge from filter effluent settling basins.

Labor and material required to keep filters running (approx.) $ 200

** If hogwood used, this figure would be about $375, giving $1600 as cost of one filter unit, or $4800 for Emporium. Hogwood gives a lighter color, but is likely to require more frequent replacement than coke. It might prove cheaper at a tannery where the wastes contained little lime.

Assuming coke used, and replaced after 18 months. Cost of new material, in place, plus cost of removing old material, less its value as fuel	1,150
One extra sludge-drying bed, at $3.25 per month to replace fine cinders, say	40
Labor for sludge removal (approx.)	100
Incidentals	10
Estimated yearly cost of primary filtration, including filter sludge handling	$ 1,500

COST OF SECONDARY FILTRATION

Including cost of handling sludge from filter effluent settling basins.

Labor and material required to keep filters running (approx.)	$ 100
Assuming hogwood used and replaced after 18 months. Cost of new material, in place, plus cost of removing old material, less its value as fuel	850
No extra sludge drying beds required. Labor for sludge removal, plus incidentals (approx.)	50
Approximate estimate of yearly cost of secondary filtration and sludge handling	$ 1,000

SUMMARIES OF ESTIMATED OPERATING COSTS

(Fixed charges not a part of these costs).

Experimental Waste Treatment Plant, Emporium*, Pa.
(Capacity 13,500 pounds raw hide per day)

	GENERAL PLAN General Mixture of Wastes Plus Plain Settlement. *Without Chemicals—No Filtration.*	*SPECIAL PLAN* Combination of Certain Wastes Plus Chemical Coagulation and Settlement. *No Filtration.*
Yearly cost of plant operation	$2,300.00	$6,700.00
Cost per 100 lb. green salted hide (13,500 lb. per day,	.055	.162
Cost per 100 lb. leather (if 100 lb. hide is equiv. to 70 lb. of leather)	.079	.231

* The Emporium tannery discharged an average total of 80,500 gal. of waste per day, produced in tanning 13,500 lbs. of hide.

Without Prior Chemical Coagulation but with *Primary Filtration,* including Filter Settling Basins		*With Prior Chemical Coagulation* Plus *Primary Filtration,* including Filter Settling Basins.	
Yearly cost of plant operation $2,300 + $1,500 (coke filtration including filter sludge handling) .	$3,800.00	$6,700 + $1,500 =	$8,200.00
Cost per 100 lb. green salted hide (13,500 lb. per day)	.092	.....	.198
Cost per 100 lb. leather (if 100 lb. hide is equiv. to 70 lb. of leather) ...	.131**	.....	.283
Without Prior Chemical Coagulation with *Primary and Secondary Filtration,* including Filter Settling Basins.		When considerable all-around improvement is required, chemical coagulation is more effective when applied after filtration (either primary or secondary), as in the General Plan above.	
Yearly cost of plant operation, $2,300 + $1,500+$1,000 (secondary coke filtration and sludge handling)	$4,800.00		
Cost per 100 lb. green salted hide (13,500 lb. per day)	.116		
Cost per 100 lb. leather (if 100 lb. hide is equiv. to 70 lb. of leather)	.166*		

SUMMARIES OF ESTIMATED OPERATING COSTS

(Fixed charges not a part of these costs).

As for a plant DOUBLE THE SIZE of that at Emporium, i.e., handling wastes from a tannery of 27,000 pounds raw hide capacity:

GENERAL PLAN General Mixture of Wastes Plus Plain Settlement. *Without Chemicals—No Filtration.*		*SPECIAL PLAN* Combination of Certain Wastes Plus Chemical Coagulation and Settlement. *No Filtration*	
Yearly cost of plant operation	$4,140.00	.....	$12,170.00
Cost per 100 lb. green salted hide (27,000 lb. per day)	.050	.....	.147

** Chemical coagulation of this primary filter effluent, with settlement and sludge handling, gives a total cost of treatment estimated at 26 cents per 100 lbs. of leather (if 100 lb. hide is equivalent to 70 lbs. of leather). This is a method for reducing color and oxygen demand during low stream flow or other emergency.

* Chemical coagulation, as above, of this secondary filter effluent gives a total cost estimated at 29 cents per 100 lbs. of leather.

Cost per 100 lb. leather (if 100 lb. hide is equiv. to 70 lb. of leather)	.072	.....	.210
Without Prior Chemical Coagulation but with *Primary Filtration,* including Filter Settling Basins.		*With Prior Chemical Coagulation* Plus *Primary Filtration,* including Filter Settling Basins.	
Yearly cost of plant operation $4,140 + $2,900 (coke filtration including filter sludge handling) ..	$7,040.00	$12,170 + $2,900 =	$15,070.00
Cost per 100 lb. green salted hide (27,000 lb. per day)	.085	.....	.182
Cost per 100 lb. leather (if 100 lb. hide is equiv. to 70 lb. of leather) .... $	.121*	..... $	.260
Without Prior Chemical Coagulation but with *Primary and Secondary Filtration,* including Filter Settling Basins		When considerable all-around improvement is required, chemical coagulation is more effective when applied after filtration (either primary or secondary), as in the General Plan above.	
Yearly cost of plant operation, $4,140 + $2,900 + $1,950 (secondary coke filtration and sludge handling)	$8,990.00		
Cost per 100 lb. green salted hide (27,000 lb. per day)	.108		
Cost per 100 lb. leather (if 100 lb. hide is equiv. to 70 lb. of leather)	.155**		

CONCLUSIONS

Two main plans of waste treatment were developed by this Committee and were given long tests at the Emporium experimental plant under, for the most part, full scale conditions. One of these is a general plan applicable in one or more of its successive steps to nearly all tanneries. After one step has been applied at a tannery, its effect can be studied and then, if necessary, further treatment can be given.

The other plan is a special one adapted to tanneries at which, in particular, definite color reduction, but only moderate reduction of oxygen demand (polluting power) is required. This special plan is

* Chemical coagulation of this primary filter effluent, with settlement and sludge handling, gives a total cost of treatment estimated at 24 cents per 100 lb. of leather (if 100 lb. hide is equivalent to 70 lbs. of leather). This is a method for reducing color and oxygen demand during low stream flow or other emergency.

** Chemical coagulation, as above, of this secondary filter effluent gives a total cost estimated at 27 cents per 100 lbs. of leather.

an effective method of waste treatment using chemical coagulation without filtration, but the cost is relatively high. Much of the improvement in color is lost during subsequent filtration.

THE GENERAL PLAN FOR WASTE TREATMENT. A possible plant is shown in the upper diagrams of Figure 7, (p. 24):

First Step: General mixture and plain settlement. Mix all the wastes in large tanks or basins, arranged to give good settlement. (Provide a nominal detention period of 8 or preferably 12 hours, and allow 30% additional capacity for sludge collection.) Permit the settled top liquid to discharge during the regular working day; or construct a storage basin large enough to permit even discharge over 24 hours. This even discharge can be regulated automatically by a simple orifice box and float valve. It lessens by 30% to 50% or more the harmful effect upon the stream without, of course, actually improving the quality of the waste itself.

Second Step: Primary filtration and settlement. Pumping will generally be necessary for this further step in purification. Use six-foot deep trickling filters equipped with revolving sprinkler arms and containing coke if the wastes are alkaline, or hogwood if they are neutral or acid. Operate for 22 to 24 hours per day.

If necessary, as an *intermediate step*, particularly in times of low stream flow, add a coagulant to the wastes as they flow from the filter. At all times pass the filtered wastes through shallow settling basins.

Third Step: Secondary filtration and settlement. Again pump the wastes. Filter as before, except that hogwood, rather than coke, can generally be used for secondary filtration. Coagulate if necessary as an *intermediate step,* and settle in final settling basins. Discharge to the stream steadily during 24 hours.

Under the SPECIAL PLAN. A possible plant is shown in Figure 0 and in the lower diagrams of Figure 7:

First Step: Combination of certain wastes, plus chemical coagulation and settlement. Mix the wastes in large tanks or basins, settle, withdraw at a uniform rate over 8 hours, dosing with the coagulant. Settle in smaller tanks, allow to overflow into settling and storage tanks. Discharge by gravity over 24 hours, using a float valve and orifice box for automatic regulation.

Second Step: Primary filtration and settlement. Pump if necessary and filter exactly as described under the "General Plan."

IN ALL CASES the following procedures should be made matters of routine:

Insure the discharge by the tannery of spent tan liquors and bleaches in approximately equal quantities from day to day. Provide sufficient vat or tank storage for this purpose.

Remove sludge periodically from all settling tanks or basins by gravity or pumping before it has become deep enough to impair their efficiency, and send to sludge drying beds or lagoons. A modified form of bed, shown in Fig. 6, (p. 19) will, it is hoped, reduce the cost of

sludge handling by reducing the quantity of fine screened cinders required for bed maintenance.

The effects of the above plans and steps in treatment, as well as the cost, are summarized in Table A, (p. 27). The results given are reasonably accurate, but those for the third step are based only on secondary filtration in model filters.

The figures indicate the following: Chemical coagulation is quite generally better and cheaper when applied after filtration. The best average color reduction is about 50%, and very little average reduction is obtained without the use of chemicals. The general plan is usually cheaper than the special, step for step (See Table B, p. 37).

The footnotes marked (*) and (**) give the effects of *Intermediate Steps A and B*—chemical coagulation applied at the entrance to the filter basins, under the general plan of treatment. Chemical coagulation can, of course, be applied before filtration under this plan if desired, although less satisfactorily than under the special plan.

The nature and polluting strength of the ingredients of typical tannery wastes have been determined.

River studies at Instanter produced much information concerning the assimilating capacity of streams for tannery waste, untreated and treated to various degrees. These studies, however, were not continued at Emporium.

Processes of treatment in successive steps, each giving an added amount of purification, have been developed.

Cost data of construction and operation have been compiled.

Therefore, many of the problems of the Tannery Waste Disposal Committee have been solved. Work remains to be done, however. The continuance of this Committee to act as a clearing house for future data may be worth while.

F. B. MILLIGAN

Assistant Resident Engineer,
Tannery Waste Disposal Committee
of Pennsylvania,
Engineer, Sanitary Water Board

APPROVED:

W. HOWALT

Resident Engineer, Tannery Waste
Disposal Committee of Pennsylvania,
Chief Engineer, Union Tanning Co.

ENDORSED AND APPROVED BY THE TANNERY WASTE DISPOSAL COMMITTEE OF PENNSYLVANIA ON OCTOBER 8, 1930.

W. L. STEVENSON, CHAIRMAN
Chief Engineer, Pennsylvania Department of Health.

T. F. OBERLANDER, SECRETARY
Chemical Engineer, Elkland Leather Co.

W. K. ALSOP
Chief Chemist, Elk Tanning Co.

A. W. HOPPENSTEDT
Consulting Chemist, J. W. & A. P. Howard Co., and West Hickory Tanning Co.

T. J. MOSSER
Chemical Engineer, J. K. Mosser Leather Corp.

H. B. NORTON
Chief Engineer, Elk Tanning Co.

B. H. ULRICH
Chief Engineer, Kistler Leather Co.

TABLE B

RELATIVE COST OF TANNERY WASTE TREATMENT BY DIFFERENT METHODS

	Kind of Treatment		% Reduction Oxygen Demand	% Reduction Color	Cost Per 100 lbs. Leather*	Cost for Each 1.6% O. D. Reduction
General Plan	1st Step	General Mixture and Settlement	41	6	$0.080	$0.00195
	2nd Step	Primary Filtration and Settlement	68	15	$0.130	$0.00191
	Intermediate Step "A"	Chemical Coagulation in Primary Filter Settling Basins	80	35	$0.260	$0.00325
	3rd Step	Secondary Filtration and Final Settlement	85	8	$0.165	$0.00194
	Intermediate Step "B"	Chemical Coagulation in Secondary Filter Settling Basins	88	50	$0.290	$0.00330
Special Plan	1st Step	General Mixture Plus Chemical Coagulation and Settlement	50	50	$0.230	$0.00460
	2nd Step	Primary Filtration and Settlement	89	28	$0.280	$0.00314

*If 100 lbs. green salted hide is equivalent to 70 lbs. of finished leather.

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